

Factors Associated with Self-reported, Pesticide-related Visits to Health Care Providers in the Agricultural Health Study

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To investigate factors associated with pesticide-related visits to health care providers (i.e., doctor or hospital visits), responses to self-administered questionnaires received from 35,879 licensed restricted-use pesticide applicators participating in the Agricultural Health Study were analyzed. (In Iowa, applicators are actually certified, whereas in North Carolina they are licensed; for ease of reference, the term license will be used for both states in this paper.) The cohort reported a total of more than 10.9 million pesticide-application days. These applications were associated with one or more pesticide-related health care visits by 2,214 applicators (7.0% of the applicator cohort for whom health care visit data were available). The odds of a pesticide-related health care visit were increased for commercial applicators compared to private applicators [odds ratio (OR) = 1.77; 95% confidence interval (CI), 1.52–2.06] and for applicators who used insecticides 70 times or more in their lifetime compared to those who used insecticides less frequently (OR = 1.43; CI, 1.26–1.63). After adjusting for the number of applications in a logistic regression model, significantly higher odds of health care visits were observed among North Carolina applicators compared to Iowa applicators (OR = 1.35; CI, 1.17–1.52), among applicators who mixed their own pesticides (OR = 1.65; CI, 1.22–2.23), and among applicators who personally repaired their pesticide application equipment at least once per year (OR = 1.12; CI, 1.06–1.25). Significantly lower odds were found among female versus male applicators (OR = 0.68; CI, 0.46–0.99) and among applicators who graduated from high school versus those who did not (OR = 0.82; CI, 0.71–0.94 for high school graduates and OR = 0.79; CI, 0.68–0.91 for those with at least some college). Several methods of pesticide application to crops, seed, or stored grain were also associated with significantly elevated odds ratios of health care visits. These observations suggest that several steps can be taken to reduce the number of health care visits resulting from occupational exposure to pesticides. The implications of this pattern of pesticide-related health care visits may have etiologic implications for cancer and other chronic diseases. *Key words:* cancers, farmers, health care visits, noncancer toxicity, occupational exposure, pesticides. *Environ Health Perspect* 106:415–420 (1998). [Online 12 June 1998] <http://ehpnet1.niehs.nih.gov/docs/1998/106p415-420alavanja/abstract.html>

Pesticides are toxic chemicals, and accidents or inappropriate use can produce symptoms that may require medical care. Few attempts have been made to systematically investigate the determinants of occupationally related pesticide poisonings in the United States. The EPA used 1971–1973 hospital records to estimate nationwide incidence rates (1). Based on extrapolations from selected hospitals, it was estimated that, nationwide, there were fewer than 3,000 hospital admissions for pesticide poisonings per year and about 66 deaths. The study, however, did not provide any indication of risk factors associated with these incidents.

Perhaps the most accurate statistics on acute pesticide poisonings come from California, where physicians are required by law to report all suspected pesticide-related cases; many of these cases are subsequently evaluated by the California Department of

Food and Agriculture (2,3). In recent years the California Department of Food and Agriculture has received between 2,000 and 2,500 reports per year of suspected pesticide poisonings (3). Slightly more than 50% of these are from confirmed occupational exposure to pesticides, 5–10% are from confirmed nonoccupational exposure, and 40–45% of the reports cannot be conclusively related to pesticide exposure.

Although the data from California are of great importance, differences in environmental conditions influence the type of pesticides applied and the methods used to apply them (4,5). Additional statistics from other parts of the United States are necessary to obtain a more comprehensive picture of the determinants of poisoning.

The Agricultural Health Study (AHS) is a large epidemiologic study of registered pesticide applicators in Iowa and North

Carolina (6). During the first 2 years of the 3-year enrollment period, more than 35,000 applicators completed a self-administered questionnaire which inquired about any hospital or doctor visits that resulted from pesticide exposure and some potential determinants of these episodes. Although the AHS was designed to evaluate cancer and other chronic disease outcomes resulting from pesticide exposures, the cohort can also be used to study factors associated with pesticide-related medical visits. While pesticide poisoning is an important public health issue in its own right, identifying the determinants of poisoning may also help evaluate the circumstances leading to biologically important exposures related to cancer and other chronic diseases.

Methods

All private and commercial applicators in Iowa and North Carolina who wish to apply restricted-use pesticides must obtain a pesticide applicator's license (in North Carolina) or become certified (in Iowa) by undergoing training or testing in the safe handling of pesticides. In Iowa, pesticide applicators must become initially certified through testing. To become recertified, applicators have the option of either being retested every third year or obtaining 2 hr continuing education each year. In North Carolina, pesticide applicator licenses are issued after training and need to be renewed every 3 years. There are two license categories in both states: private applicators (primarily farmers) constitute 70% of licensed applicators, and commercial applicators comprise the remaining 30% and

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include persons employed by agricultural dealerships, pest control companies, or by businesses that use pesticides but whose primary function is not pesticide application, e.g., golf course managers. All certified applicators in both states are therefore available for enrollment into our study at the certification/recertification offices every 3 years.

At the testing or training session, each pesticide applicator was asked to read the informed consent and then complete a 21-page optically scannable enrollment questionnaire. In Iowa, commercial and private applicators attend the same sessions, and all applicators were invited to participate in the study. In North Carolina, private and commercial applicators attend separate training sessions; only private applicators from North Carolina were enrolled. The enrollment questionnaire obtained general information on the use of pesticides as well as information on 50 specific pesticides. For 22 of these pesticides, this included the number of years a specific pesticide was used and the average number of days of

application per year. Additional questions included the use of protective clothing, the equipment used when applying pesticides, whether pesticides were personally mixed by the applicator, whether pesticide equipment was personally repaired by the applicator, the state of residence (Iowa, North Carolina), and the pesticide license or applicator certification type (private, commercial). The questionnaire also included questions about 38 types of crops and livestock raised in the past year, farm size in acres, smoking and alcohol consumption (analyzed by quartiles of lifetime consumption), fruit and vegetable intake (quartiles of consumption of fruits and vegetable analyzed separately and combined), as well as basic demographic data, analyzed as age in 10-year categories (15–24, 25–34, 35–44, 45–54, 55–64, 65 and older), gender, education (analyzed as less than 12 years, high school graduate, and at least some college), and race (analyzed as white, black, and “other racial groups”). Quartiles of cumulative lifetime herbicide, insecticide, fumigant, and fungicide application days were

determined by multiplying the number of days of application per year by number of years. Analysis was based on the first 2 years of enrollment; after the third year of enrollment, analysis by specific pesticides will be possible.

Health care visits resulting from pesticide use were ascertained in the enrollment questionnaire from the question: “As a result of using pesticides, how often have you: a) seen a doctor [or] b) been hospitalized.” Visits to a doctor or hospital were added together to determine number of health care visits. Since both the occurrence of a health care visit and the potential risk factors were ascertained by the same questionnaire, the analysis was cross-sectional.

Multivariate logistic regression methods were used to estimate relative risk (odds ratio; OR) and the 95% confidence interval (CI) (7). Visits to a health care facility resulting from pesticide use were analyzed as a dichotomous variable (i.e., ever vs. never visited a doctor or hospital) and by the number of visits (none, one, and two or more). Since the general pattern of risk resulting from the use of either form of the dependent variable was not appreciably altered, we used only the dichotomous form of the variable to concisely present our results. Independent variables were introduced into the model by both a forward addition and backward elimination procedure available in SAS [SAS Institute, Cary, NC (8)].

Results

The enrollment participation rate for the first 2 years was 70% (i.e., 35,879 pesticide applicators completed the enrollment questionnaire out of 51,256 applicators who attended the training or testing sessions in both states) (Table 1). In Iowa, 16,193 private applicators and 4,897 commercial applicators enrolled in the study; in North Carolina, 14,789 private applicators enrolled. We chose to report these results based on 2 years of enrollment data because the number of outcome events was sufficiently powerful for statistical analysis; the 2-year sample represented a random selection of study subjects from the 3-year cohort, thereby not biasing the results; and the findings were judged to have important public health significance dictating prompt reporting of results.

About 3% of the applicators enrolled in the study were women and 3.1% were minorities, reflecting the general proportion of race and gender groups seeking licenses in the study area. A large proportion of the nonwhite applicators were African American and most (98%) lived in North Carolina. The median age of private

Table 1. Demographic characteristics of the Agricultural Health Study cohort

Characteristic	IA Private		IA Commercial		NC Private		Total	
	n	%	n	%	n	%	n	%
Sex								
Male	15,365	98.6	4,442	96.1	13,556	95.5	33,363	97.0
Female	215	1.4	178	3.9	641	4.5	1,034	3.0
Unknown	613		277		592		1,482	
Race								
White	14,951	99.9	4,596	99.5	12,609	92.7	32,156	96.9
Black	11	0.1	6	0.1	814	6.0	831	2.5
Others	11	0.1	19	0.4	176	1.3	206	0.6
Unknown	1,220		276		1,190		2,686	
Marital status								
Married	13,159	84.5	3,442	74.5	11,651	81.7	28,252	82.0
Divorced	547	3.5	347	7.5	823	5.8	1,717	5.0
Widowed	101	0.6	18	0.4	259	1.8	378	1.1
Never married	1,771	11.4	813	17.6	1,532	10.7	4,116	11.9
Unknown	615		277		524		1,416	
Age (years)								
<25	435	2.9	466	10.2	497	3.8	1,398	4.3
25–34	2,362	15.7	1,246	27.3	1,709	13.2	5,317	16.3
35–44	4,680	31.0	1,599	35.1	3,081	23.8	9,360	28.7
45–54	3,452	22.9	761	16.7	3,109	24.0	7,322	22.5
55–64	2,829	18.8	371	8.1	2,529	19.5	5,729	17.6
≥65	1,316	8.7	117	2.6	2,043	15.8	3,476	10.7
Unknown	1,119		337		1,821		3,277	
Median age	45		38		48		45	
Years of education								
<12	835	5.7	142	3.2	2,335	17.9	3,312	10.3
High school or equivalent	7,415	50.4	1,928	42.8	5,802	44.4	15,145	46.9
College/technical school	6,114	41.5	2,283	50.7	4,386	33.5	12,783	39.6
Graduate school	353	2.4	148	3.3	557	4.3	1,058	3.3
Unknown	1,476		396		1,709		3,581	
Smoking status								
Never smoked	9,132	60.7	2,181	48.1	5,313	41.8	16,626	51.5
Former smoker	4,152	27.6	1,189	26.2	4,409	34.7	9,750	30.2
Current smoker	1,750	11.6	1,160	25.6	2,978	23.4	5,888	18.2
Unknown	1,159		367		2,089		1,528	
Total	16,193		4,897		14,789		35,879	

Abbreviations: IA, Iowa; NC, North Carolina.

applicators was 45 years in Iowa and 48 years in North Carolina. Commercial applicators were significantly younger (median age of 38 years) than private applicators in North Carolina or Iowa. Over 80% of the private applicators were married, compared to about 75% of the commercial applicators. Although 90% of the applicators graduated from high school and approximately 40% completed some college, almost 18% of North Carolina applicators did not graduate from high school, compared to 5.7% of Iowa private applicators and 3.2% of commercial (Iowa) applicators. A larger portion of commercial applicators attended college than private applicators (54% vs. 44%, respectively). Overall, 18.2% of the applicators were current smokers, which is lower than the rate for the U.S. population, in general (28% for males) (9). Smoking was more common among commercial applicators in Iowa (25.6%) than among private applicators in Iowa (11.6%) or private applicators in North Carolina (23.4%).

Among commercial applicators, 45% applied herbicides to crops, 37% applied pesticides to lawns and gardens, 25% applied insecticides to crops, 13% applied pesticides to homes, and 4% were engaged in forestry applications. Although they were younger and had somewhat fewer years of experience applying pesticides, commercial applicators tended to mix or apply pesticides more frequently than private applicators.

The 31,764 members of this cohort who answered the questions regarding visits to a doctor or hospital resulting from pesticide exposure have more than 10.9 million pesticide application days (Table 2). The mean number of application days for private applicators was 17 for Iowa and 26 for North Carolina. The distribution of pesticide applications was highly skewed toward a larger number of applications, as evidenced by wide interquartile ranges and the asymmetric location of the arithmetic means relative to the 25th and 75th percentiles. Commercial applicators in Iowa were involved in pesticide applications more than twice as frequently as private applicators.

Of the pesticide applicators, 7% ($n = 2,214$) reported they actually made a medical visit because of pesticides (Table 3). This proportion varies from 6.3% among Iowa private applicators to 7.2% among North Carolina private applicators and 8.3% in Iowa commercial applicators. A total of 3,733 visits to health care facilities were reported by the cohort, or approximately 3 health care visits for every 10,000 pesticide applications.

Table 2. Mean number of days pesticides were applied per year and total number of applications made by state and license type

	IA Private	IA Commercial	NC Private	Total
Mean days per year	17	45	26	24
Interquartile range (25 th –75 th percentile)	7–15	15–50	7–30	7–30
Total applications (n) ^a	4,004,308	1,915,707	5,067,622	10,987,637

Abbreviations: IA, Iowa; NC, North Carolina.

^aNumber of applications = number of days of application per year \times number of years of application.

Table 3. Total number of health care visits resulting from pesticide exposure by state and license type

	IA Private	IA Commercial	NC Private	Total
Unaffected persons	13,735	4,149	11,666	29,550
Affected persons	928	377	909	2,214
White males	882	361	790	2,033
Black males	1	0	51	52
Other males	0	1	13	14
White females	8	4	20	32
Black and other females	0	0	1	1
Unknown	37	11	34	82
Number of doctor visits	1,294	570	1,389	3,253
Number of hospital visits	140	56	284	480
Total combined health care visits	1,434	626	1,673	3,733

Abbreviations: IA, Iowa; NC, North Carolina.

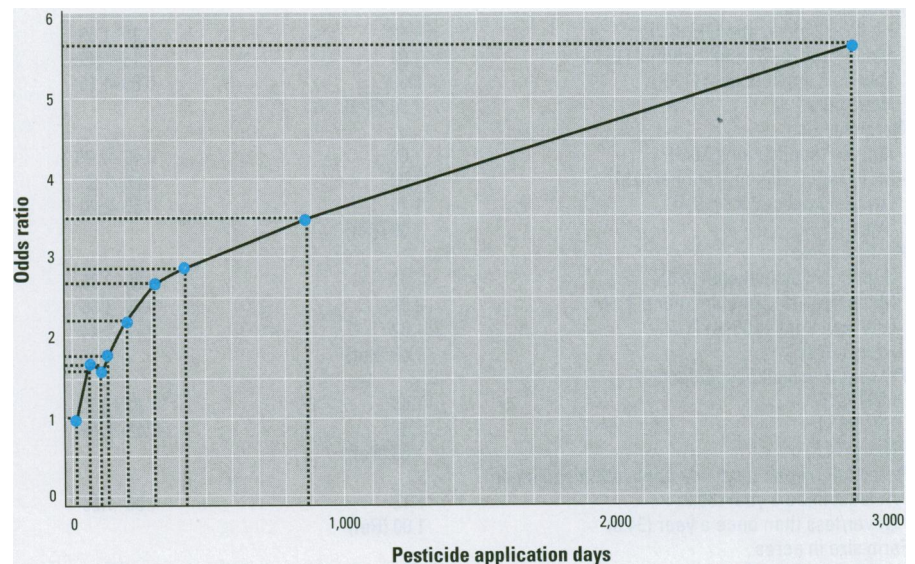


Figure 1. Risk (odds ratio) of health care visits due to pesticide exposure by total number of pesticide application days (in deciles).

Figure 1 and Table 4 show the risk (odds ratio; OR) of a pesticide-related health care visit by the total days of pesticide application in deciles (average days of application multiplied by total years of application). The reference group comprised applicators who applied pesticides 3–24 days. The risk of pesticide-related visits to a doctor or hospital increased with the total number of pesticide applications.

The application characteristics associated with pesticide-related visits to a hospital or doctor are listed in Table 5. After accounting for number of pesticide applicators [OR

Table 4. Odds ratios for total days of exposure shown in Figure 1

Total days of exposure		
Range	Mid-point	Odds ratio
3–24	13.5	1.00 (Reference)
24.5–52.5	38.5	1.10
53–105	79	1.68
106–120	113	1.63
121–178.5	149.75	1.84
179–240	209.5	2.24
241–400	320.5	2.65
400.5–465	432.75	2.92
466–1,275	870.5	3.50
1,276–4,500	2,888	5.78

= 0.68; 95% confidence interval (CI), 0.46–0.99] and among applicators who had finished high school compared to those who did not finish high school (OR = 0.82; CI,

0.71–0.94). Applicators who had completed some college (which included college graduates and those with graduate education) had the same risk as those who had

only completed high school (OR = 0.79, CI, 0.68–0.91). The odds of a pesticide-related visit were higher among North Carolina applicators than among Iowa applicators (OR = 1.33; CI, 1.17–1.52) and among commercial applicators than among private applicators (OR = 1.77; CI, 1.552–2.06). Applicators who used insecticides 25–70 times had higher odds [OR = 1.31; CI, 1.15–1.49) than those who did not use insecticides, as did those who had used insecticides 70 or more times (OR = 1.43; CI, 1.26–1.63). No trend was seen with increasing use of herbicides or fungicides, but a nonsignificant 41% excess was observed in the highest fumigant use category (i.e., greater than 28 fumigant applications) compared to those who did not use fumigants. Applicators who mixed pesticides were at significantly increased odds for pesticide-related medical visits compared to those who did not (mixed less than 50%: OR = 1.63, CI, 1.19–2.16; mixed greater than 50% of the time: OR = 1.65, CI, 1.22–2.23), but no meaningful gradient of risk was observed by frequency of mixing pesticides. Personally repairing pesticide application equipment was also associated with excess health care visits (OR = 1.12; CI, 1.06–1.25). Pesticide application methods covered in the questionnaire included airblast, boom on tractor truck or trailer, hand spray gun, backpack sprayer, mist blower/fogger, aerial (aircraft application), in furrow or banded, seed treatment, distributed tablets/granules, pouring fumigant from bucket, gas canister, row fumigation, powder duster, injection of animals, dipping animals, spraying animals, ear tags, and dusting or pouring on animals. Most applicators tended to use a variety of these techniques to apply pesticides, but several were associated with greater risk of a health care visit. These included pouring fumigants from buckets (OR = 1.44; CI, 1.16–1.79), dipping animals (OR = 1.30; CI, 1.14–1.48), use of mist blower/foggers (OR = 1.27; CI, 1.08–1.49), row fumigation (OR = 1.26; CI, 1.06–1.50), use of a gas canister (OR = 1.22; CI, 1.03–1.44), seed treatment (OR = 1.21; CI, 1.08–1.35), and application of ear tags (OR = 1.18; CI, 1.04–1.34). Dusting animals (OR = 0.85; CI, 0.75–0.96) was associated with a reduced risk. Applicators with farms 200–499 acres (OR = 1.14; CI, 1.00–1.30) and those with farms >500 acres (farms 500–999 acres: OR = 1.37, CI, 1.19–1.58; farm size >1,000 acres: OR = 1.39, CI, 1.19–1.62) were at greater risk than those applicators with < 200 acres. The benefit of the general use of personal protective equipment was not observed in this study. Risk was not associated with age, race, smoking

Table 5. Applicator characteristics associated with health care visits due to exposure to pesticides

Characteristic ^a	Odds ratio ^{b,c}	95% Confidence intervals
Sex		
Female (2.3)	0.68	0.46–0.99
Male (97.7)	1.00 (Ref)	
Education		
Some college (44.5)	0.79	0.68–0.91
High school graduate (45.1)	0.82	0.71–0.94
<12 years (10.4)	1.00 (Ref)	
State of residence		
North Carolina (38.9)	1.33	1.17–1.52
Iowa (61.1)	1.00 (Ref)	
License type		
Commercial (13.5)	1.77	1.52–2.06
Private (86.5)	1.00 (Ref)	
Protective equipment used		
Yes (70.1)	1.10	0.98–1.23
No (29.9)	1.00 (Ref)	
Herbicide use		
High (>168 applications) (24.3)	0.97	0.84–1.11
Moderate (42–168 applications) (26.3)	1.02	0.90–1.16
Low (<42 applications) (20.2)	0.85	0.74–0.98
None (29.2)	1.00 (Ref)	
Insecticide use		
High (>70 applications) (15.7)	1.43	1.26–1.63
Moderate (25–70 applications) (15.2)	1.31	1.15–1.49
Low (<25 applications) (12.6)	0.99	0.85–1.15
None (29.2)	1.00 (Ref)	
Fungicide use		
High (>8 applications) (0.2)	1.09	0.43–2.75
Moderate (4–8 applications) (0.5)	1.03	0.58–1.83
Low (<4 applications) (0.4)	1.10	0.55–2.20
None (29.2)	1.00 (Ref)	
Fumigant use		
High (>28 applications) (0.5)	1.41	0.85–2.35
Moderate (14–28 applications) (1.7)	0.99	0.70–1.36
Low (<14 applications) (1.7)	1.02	0.72–1.44
None (29.2)	1.00 (Ref)	
Personally mixed pesticides		
>50 (68.9)	1.65	1.22–2.23
<50 (26.6)	1.63	1.19–2.16
Never (4.5)	1.00 (Ref)	
Personally repair pesticide application equipment		
At least once a year (65.2)	1.12	1.06–1.25
Never/less than once a year (34.8)	1.00 (Ref)	
Farm size in acres		
≥1000 acres (12.3)	1.39	1.19–1.62
500–999 acres (18.3)	1.37	1.19–1.58
200–499 acres (23.0)	1.14	1.00–1.30
Not farming (5.0)	1.08	0.87–1.34
<200 acres (41.4)	1.00 (Ref)	
Application method		
Mist blower/fogger	1.27	1.08–1.49
Seed treatment	1.20	1.07–1.34
Pour fumigant from bucket	1.44	1.16–1.79
Gas canister	1.22	1.03–1.45
Row fumigation	1.23	1.04–1.46
Dip animals	1.30	1.14–1.48
Ear tags	1.18	1.04–1.35
Dust/pour on animals	0.85	0.75–0.96
Other	0.80	0.63–1.02
Do not apply/none of methods	1.00 (Ref)	

Ref, reference.

^aValues in parentheses are percent.

^bAdjusted for race, age, and other variables listed in this table.

^cAn odds ratio (OR) >1 indicates that the subgroup is more likely to have visited a doctor or hospital relative to the referent category, while an OR <1 indicates the subgroup is less likely to have visited a doctor or hospital.

patterns, alcohol consumption, or fruit and vegetable consumption.

Discussion

In this large cross-sectional analysis of pesticide applicators, the frequency of insecticide use, a number of demographic variables, and several work practices were significantly associated with pesticide-related visits to a doctor or hospital. If these associations are judged to be determinants of pesticide poisoning, some of these risk factors (e.g., the high risk associated with mixing pesticides and repairing pesticide equipment) appear to be amenable to correction with additional engineering controls, training, or education. The key behavioral or occupational determinants of risk for other independent variables (e.g., sex, state of residence) associated with excess health care visits, however, are not obvious and will require further research.

Significantly fewer pesticide-related visits were reported by applicators who had graduated from high school compared to those who had not. The estimated level of risk reduction associated with completing high school could not be explained by the total number of application days, work practices used, or the other risk factors identified. Because no additional increment of protection is afforded by completing college or graduate study, it may be that illiteracy or poor reading skills is a risk factor of pesticide intoxication. Although we have no data on the reading skills of this cohort, anecdotal reports from our field staff suggest that some applicators required the assistance of a "reader" who helped read the forms and test material. Limitations in reading skills would be expected to be most prevalent in the group that had not completed high school. More data need to be collected before a firm conclusion can be reached, but an education program (or special labeling such as differentially colored labels) for safe pesticide application designed for the reading impaired should be considered.

The odds of pesticide-related health care visits among female applicators is significantly lower than that of male applicators when other co-factors are controlled. The reason for this observation is not clear. Because the epidemiologic literature suggests that women seek medical care more freely than men (10), the actual difference in the relative odds of a health care visit may be understated here. Men more frequently use certain pesticide application techniques than women, and these techniques may be associated with the use of more toxic chemicals or a greater opportunity for overexposure. These application techniques (e.g., spraying animals, row

fumigation, seed treatment) have been associated with greater odds of pesticide-related health care visits in our data, but there is an additional risk for males that is not explained by these variables. On the other hand, female applicators may adhere to recommended safe work practices more closely than their male counterparts. The difference in risk is substantial, and an elucidation of factors involved might prove useful in preventive programs.

Commercial applicators reported 51% more visits to hospitals and doctor's offices than private applicators. Although differences in the application methods used by commercial or private applicators were not apparent in our data, farmers may hire commercial applicators for tasks inherently more dangerous, and perform less dangerous applications themselves. We know of no data to support this possibility; however, in a study from Sweden (11), professional spraymen had higher urinary levels of several herbicides than farmers. Alternatively, commercial applicators may be more inclined to visit a doctor or hospital because commercial applicators may be covered by health insurance more frequently than farmers. In a study of two rural Vermont hospitals, farmers were less likely to use insurance to cover hospital costs than other patients from the county (12).

Other factors have been associated with health-care seeking behavior (13). Because we do not have information on the seriousness of the event that led to the self-reported visits, the issue of differential use of services or differential reporting must be considered. Persons of lower social class and nonwhite race incur more physician visits and hospitalizations than whites and those with higher incomes. This could be due to a greater medical need or to differences in behavior. Availability of care is also an issue; with fewer physicians per capita in rural areas, the frequency of health care visits may be less. To some extent, the homogeneity of this cohort minimizes the potential impact of some of these factors. Further, it has been demonstrated that health status is the most important determinant of the use of health care services (13).

The bulk of exposure to herbicides occurs from dermal contact rather than from inhalation (14–16). This suggests that mixer-loader operations may result in higher exposure than many application scenarios. On the other hand, a study of urinary levels of atrazine found little difference in levels between applicators and mixer-loaders (17). We observed that applicators who mixed pesticides were at 67% greater risk of pesticide-related health care visits than applicators who did not. Training in techniques

that reduce exposure during mixing might be effective. In addition, some emerging methods, such as enclosed delivery systems (e.g., "lock and load") may reduce intoxication from this work practice. Applicators who repair their own pesticide application equipment were also significantly more likely to incur a health care visit from a pesticide than were applicators who did not repair their own equipment. Repair of pesticide application equipment should be performed cautiously, with great priority given to reducing personal pesticide exposure.

The acute human toxicity of insecticides and fumigants is generally greater than that of herbicides (18–20). It may be this greater toxicity rather than a greater potential for exposure that was responsible for the excess risk of intoxication observed with increasing numbers of insecticide applications. Although the gradient of toxicity of different pesticides is well understood by toxicologists and conveyed to applicators through EPA-mandated signal words (e.g., "caution," "warning," "danger"), this information may need greater prominence on pesticide labels or containers. Although the relative scarcity of approved insecticides for a particular insect pest may give applicators little choice in selecting insecticides based on toxicity, training may need to emphasize the use of improved work practices and incorporating engineering controls.

Use of protective equipment was not associated with a reduction in risk in this analysis. However, enrollment data on protective equipment was limited. In our analysis we compared those who answered that they "generally wear" protective equipment [e.g., cartridge respirator, face shield or goggles, disposable outer clothing (like Tyvek), chemically resistant gloves and other protective clothing (boots, aprons, waterproof pants)] to those who said they do not generally use any protective equipment. We had no data on the regularity of use or on use at the time of the reported pesticide-associated medical visits; we also had no information on whether equipment was used correctly. Future analyses based on more in-depth supplemental and followup questionnaires may provide a better estimate of the value of specific types of protective clothing/equipment and other work practices when handling pesticides. From a previous analysis (21), it is clear that the frequency and appropriateness of protective equipment being worn varies by state and that simple protective measures are not uniformly applied. For example, many applicators used fabric or leather gloves rather than chemically resistant gloves during pesticide application; this is

not recommended and may actually increase exposure to pesticides.

The large size and high participation rate of pesticide applicators in the Agricultural Health Study allowed detailed evaluation and more confident extrapolation to the larger applicator population. Previous studies (22–24) have also established that farmers, who constitute 80% of the current cohort, are very knowledgeable about the types and amounts of pesticide that they have applied to their farms, leading us to believe that data on the amounts and circumstances of pesticide use are reasonably accurate. For example, applicators keep records of pesticide applications not only for state needs but for fiscal records of their expenses for the Internal Revenue Service.

Although the Agricultural Health Study is prospective in design, the analysis here is cross-sectional. Because data on exposure and effect are obtained at the same time, cross-sectional analyses may introduce a selection bias resulting from differential follow-up of highly exposed and less highly exposed applicators. For example, individuals who suffered from pesticide poisoning that resulted in death, disability, or a decision to discontinue applying pesticides would not be included in this cohort. This could reduce the estimated frequency of health care visits resulting from pesticides. It would not, however, distort the pattern of risk associated with individual risk factors identified in this study unless there was a selective nonresponse for individuals with both a particular exposure and a visit to a health care provider. This could occur if recall about pesticide use was better among participants who experienced an exposure requiring medical care. Two additional limitations of the current study are that the outcome variable is based on unverified self-reports and the circumstances surrounding the health care visit were not ascertained in the current questionnaire. In California, self-reported episodes of pesticide intoxication could not be verified by the attending physician in 40–45% of the cases. The self-reports of intoxication in the

Agricultural Health Study may suffer from the same problem. Thus, measures of association have been identified, but making cause-and-effect conclusions from these associations or estimating the precise incident rate of pesticide intoxications may not be appropriate. Because the data are reported here in the form of relative odds (i.e., odds ratios) and not as an absolute risk rate, we do not anticipate a bias in reporting that would distort these risk estimates.

Most previous studies of pesticide applicators have been of a case-control design, and exposure assessment may have been incomplete and subject to case-recall bias. This analysis suffers from the same limitations, but the prospective cohort design of the Agricultural Health Study will permit us to minimize this concern in future years. This initial cross-sectional analysis of baseline data on the pesticide intoxication experience of the cohort itself has identified important exposure scenarios. These findings can be used to develop preventive strategies and to refine our future epidemiologic investigation of cancer and other chronic diseases.

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